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Native vs broiler meat after gamma irradiation treatment: Color and surface image study

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Abstract. In recent decades, food irradiation has been at the center of many different meat preservation investigations. In future decades, Indonesia will increase its exports of poultry meat products in response to an increasing trend. To our knowledge, no study has investigated the differences between native and broiler chicken meat post gamma irradiation treatment. Therefore, this study aimed to compare the effect of gamma irradiation on color, pH and surface image of native and broiler chicken meat. The treatments observed in this study were two types of chicken meat (native vs broiler) which were gamma irradiated at doses of 0, 5 and 10 kGy. Three replicates were used in all parameters except in surface image study by SEM and mineral analysis. Lightness (L^*) at day 0 and 14 was decreased due to irradiation ($p<0.05$), both in broiler and native chicken meat. After storage at day 14, native chicken meat after gamma irradiation had the highest redness (a^*) value ($p<0.05$). However, no significant differences were found in yellowness (b^*). Based on the various types of meat, the results reveal that there was no statistical difference in pH values between irradiation dosage. However, native chicken irradiated with 10 kGy had the highest pH value in 0 and 14 days of storage ($p<0.05$). Regardless of the kind of meat, gamma irradiation may affect the surface image of the sample. After irradiation treatment, it has been suggested that variations in muscle structure are responsible for differences in surface appearance. We concluded that, meat color, both in broiler and native chicken meat was affected by gamma irradiation treatment. However, no significant differences were found in pH values. Gamma irradiation may influence the surface image of the sample. Larger particles and aggregates were observed after treated with 5 and 10 kGy irradiation.

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1 Introduction

From January to May of 2021, Indonesia's exports of poultry products reached 258,85 tonnes, an increase of 12.98% compared to the same period the previous year [1]. In future decades, Indonesia will increase its exports of poultry meat products in response to an increasing trend. Therefore, animal product preservation technology is required take advantage on this opportunity. The current demand of consumers is for clean and secure food that does not compromise the nutritional and sensorial qualities. Food safety is an international issue requiring a global response. Food chain approval is a complex process involving poultry, harvesting, transportation, slaughtering, packaging, sale, and consuming products from farms [2]. This moved the focus of food professionals towards the creation of non-thermal technologies for preservation that are green, secure, and environmentally friendly [3].

Ultrasound treatments, high-pressure hydrostatic processing, and gamma and irradiation treatments are the most widely used industrial applications with the potential to inhibit pathogenic microorganisms prevalent in meat products [4]. In recent decades, food irradiation, an emerging environmentally friendly technology, has been at the center of many different food preservation investigations [5]. Irradiation is an effective method of food preservation due to eliminates or minimizes pathogens, parasites, and pests without significantly altering the food's chemical composition, thus ensuring its safety [6]. A maximum dose of 10 kGy has been suggested for food irradiation, without any requirement for toxicological or nutritional evaluation. These doses have no effect on the overall flavor of foods [6]. Depending on the irradiation dose and the type of meat, applying irradiation on food products might result in free radicals, color changes, lipid oxidation, and an increase of unpleasant odours [7]. Additionally, the procedure breaks down some of the food's molecules, which can have an impact on its nutritional value and sensory qualities. To our knowledge, recently, there is no research that has investigated the differences between native and broiler chicken meat post gamma irradiation treatment. Therefore, this study is a preliminary investigation through this issue. The purpose of this experiment was to compare the effect of gamma irradiation on color, pH and surface image of native and broiler chicken meat.

2 Experimental procedures

2.1 Sample preparation

Native and broiler chicken samples were purchased from a modern market in Gunungkidul, Yogyakarta. About 20–30 g of minced meat was anaerobically packed by polypropylene bags using vacuum sealer. Samples were stored at a temperature -18°C for 48 h before irradiated.

2.2 Experimental design

The treatments observed in this study were two types of chicken meat (native vs broiler) which were gamma irradiated at doses of 0, 5 and 10 kGy. The first factor was meat type and the second factor was irradiation dose. The observed parameters are color, pH, surface image, and mineral content. Color (L*, a*, and b*) and pH value were evaluated after 0, 7, and 14 d of refrigerated storage (2°C). Three replicates were used in all parameters except in surface image study by SEM and mineral analysis.

2.3 Gamma irradiation

Gamma irradiation was performed at Irradiator Laboratory, which is under the Indonesian Polytechnic of Nuclear Technology, National Research and Innovation Agency. Under chilled conditions, the Gamma Cell 220 Upgraded (Izotop, Hungary) was applied to irradiate samples with doses of 0, 5, and 10 kGy. During radiation, the dose rate was 2.81 kGy/h.

2.4 Color

The surface color values of the untreated and irradiated meat samples were determined using Chromameter Konica Minolta (Konica Minolta, Tokyo, Japan). Color values expressed as lightness (L^*), redness (a^*), and yellowness (b^*) by using average from three samples replicate.

2.5 pH

pH value of untreated and irradiated meat was measured using pH meter (Eutech Instruments PC700) from meat homogenate. The homogenate meat was prepared by blending approximately 4 g of meat with 8 ml destilled water.

2.6 Scanning Electron Microscope (SEM)

Untreated and irradiated meat was dried in the oven for 120 h at 55°C. Using a Scanning Electron Microscope (SEM), surface area characteristics of dry meat were evaluated. As a conductor, the sample was placed in a gold- and palladium-coated plate before observation. Observations conducted at 15kV accelerated energy. At 3000 magnification, the obtained images were compared and observed in detail.

2.7 Mineral measurement

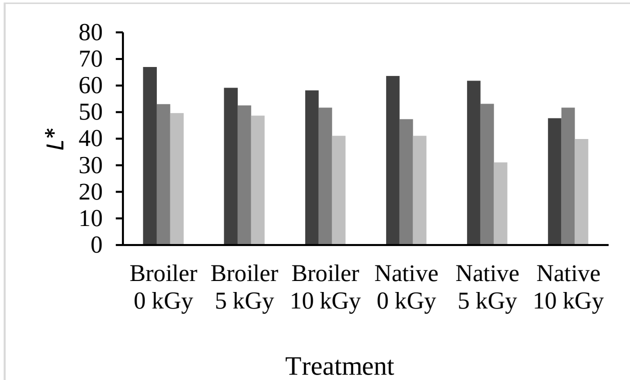
The mineral content was determined using X-Ray Fluorescence (XRF). Meat sample was placed in the pellet press to be completely vacuumed before being exposed to 50 kV X-rays. The instrument (Panalytical epilson 4) needs about 8 minutes to measure a sample.

2.8 Statistical Analysis

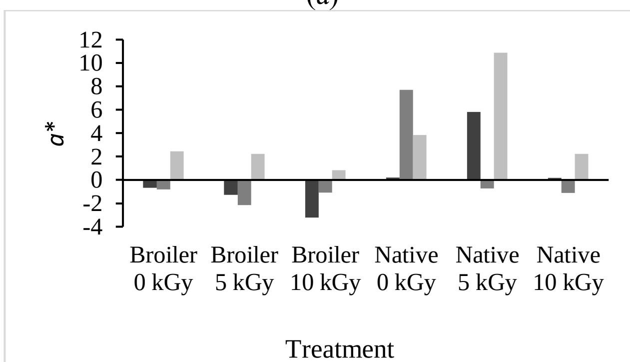
The data was evaluated using a completely randomized design with two-factor. The first factor was meat type and the second factor was irradiation dose. SPSS version 25.0 was applied for analysis of variance on the data. The Duncan's Multiple Range Test was used for evaluating all mean comparisons [8].

3 Results and discussion

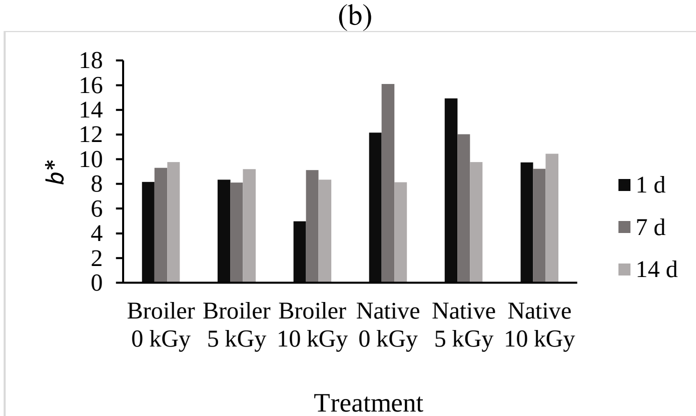
Color values, expressed as lightness (L^*), redness (a^*), and yellowness (b^*) are shown in Figure 1. In present study, differences in meat type affected the overall value of the meat's color ($p<0.05$), except for parameters L^* day 0 and b^* day 14. There was no interaction between meat type and dose of irradiation. Gamma irradiation can decrease the value of parameters L^* (0 and 14 d) and a^* (0 and 7) ($p<0.05$). However, the results for parameter b lack a consistent pattern. Nevertheless, the yellowness (b^*) of native chicken meat is greater than broiler chicken ($p<0.05$).



(a)



(b)



(c)

Fig. 1. Lightness (*L**; a), redness (*a**; b), and yellowness (*b**; c) values of broiler and native chicken meat after gamma irradiation treatment and storage at 0, 7, and 14 d.

In contrary, Arshad et al. [9] reported that *L** and *a** value of poultry breast was increased by irradiation. This difference may be due to differences in the part/composition of the irradiated meat. In present study, chicken meat with skin were utilized. High lipid concentrations in raw materials make them more vulnerable to oxidation and discoloration [10]. Ahn et al. [11] demonstrated that animal species, irradiation dose and muscle type influence the color variations in irradiated meat. Khalid et al. [12] reported that variable *b** (yellowness) was the main factor for the color variability, since chicken meat was basically yellow. Iron, as myoglobin molecules, are sensitive to chemical alterations as well as modifications in energy input, which altered the structure of the irradiated meat during refrigeration [10, 13]. Due to differences in pigmentation, the value of *a** is greater in native than broiler meat. Oxymyoglobin is associated with greater *a** values than myoglobin or metmyoglobin (14).

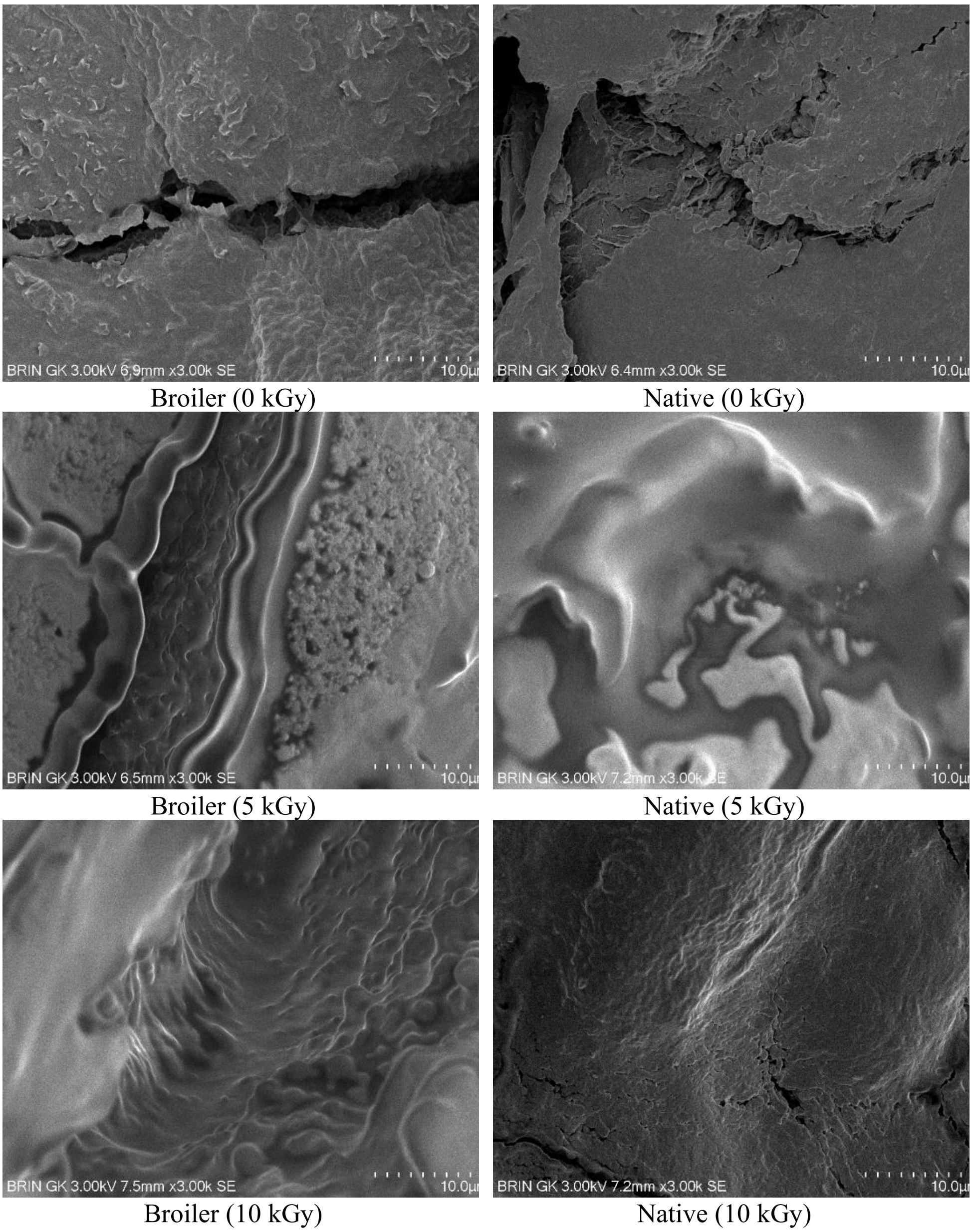


Fig. 2. Scanning electron microscopy (SEM) of untreated and gamma irradiated chicken meat at 3000x magnification.

Figure 2 present SEM image of the surfage image study of broiler and native meat after gamma irradiation treatment at 3000x magnification. Regardless of the kind of meat, gamma irradiation may affect the surface image of the sample. The irradiation process causes meat differences that are only detectable with the SEM test. After irradiation treatment, it has been suggested that variations in muscle structure are responsible for differences in surface appearance. Previous study reported that the low dose (range of 2.2 to 2.9 kGy) of gamma irradiation induced significant textural increasing of cooked chicken breast meat, restriction of sarcomere width, and physical breakdown of myofibril units in muscle fibers [15]. Changes in the protein structure of the meat may also contribute to irradiation-induced visual changes. In different samples, the scanning electron microscopy illustrations revealed that initially, whey protein had a fairly uniform structure, however after gamma radiation, aggregated particles formed [16]. Furthermore, Wang et al. [16] reported that Scanning electron micrographs of samples of whey protein treated with 15 and 25 kGy indicated larger particles and aggregates, particularly for samples treated with 25 kGy.

Table 1. pH value of broiler and native chicken meat after gamma irradiation treatment.

Meat type	**Irradiation dosage (kGy)**	**Storage period (d)**		
		0	**7**	**14**
Broiler	0	6.28d	6.15d	6.12a
	5	5.73a	6.37f	6.37b
	10	5.98b	5.94b	6.14a
Native	0	6.18c	6.23e	6.53c
	5	6.24d	5.80a	6.32b
	10	6.52e	6.07c	6.59d
SEM		0.060	0.045	0.044
Meat type		*	ns	**
Irradiation dosage		ns	ns	ns
Meat type vs Irradiation dose		ns	ns	ns

Different letters in the same row indicate significant differences ($p < 0.05$), Standard Error of the Means (SEM).

The pH value of broiler and native chicken meat samples irradiated at doses of 5 and 10 kGy during 14-day storage are shown in Table 1. Based on the various types of meat, the results reveal that there was no statistical difference in pH values between irradiation dosage. However, native chicken irradiated with 10 kGy had the highest pH value in 0 and 14 days of storage ($p<0.05$). Whereas at 7 days of storage, broiler meat irradiated at 5 kGy had the greatest pH value of 6.37 ($p<0.05$). The pH value at 0 and 14 days of storage varies based on the type of meat ($p<0.05$). There is no interaction between meat type and irradiation dosage.

In our study, gamma irradiation dosage had no significant effect on pH value. This may be the result of the inhibition of bacterial growth, which may delay the synthesis of alkaline chemicals, thereby sustaining a stable pH level during storage [17]. Previous research investigations also revealed similar results [18–20]. It should be noted that in this study, chicken meat contained no additional ingredients. In several studies, pH changes in post-irradiated meat were induced by interactions between radiation and additional treatments, such as the addition of chitosan [20] and herbs [21]. The pH value is also represented by the color of chicken meat; the lower the pH, the paler the color [22]. At 0 and 14 days of storage, it is interesting to note that, native chicken meat exposed to 10 kGy radiation produced a higher pH than broiler meat ($p<0.05$). This will affect the appearance of color and consumer acceptability. Normal breast pH is between 5.91 and 6.02, whereas pH 5.88 to 5.84 indicates a pale, soft, exudative breast, and pH 6.35 to 6.4 indicates a dark, firm, dry-looking breast [23]. However, the difference in pH value may also be influenced by differences in the part of meat and the slaughter age of the chicken [24].

Table 2. Mineral content of broiler and native chicken meat after gamma irradiation treatment.

	Broiler			**Native**		
	Irradiation dose (kGy)					
Macro-minerals (%)	0	5	10	0	5	10
P	13.18	11.88	11.61	12.53	11.34	11.86
S	12.47	13.49	13.94	15.33	15.54	15.64
Cl	11.64	11.04	11.69	11.92	10.62	11.17
K	49.99	51.49	50.10	46.98	45.89	44.34
Ca	10.55	9.99	10.49	10.79	14.41	14.66
Micro-minerals (ppm)						
Zn	0.1	0	0.1	0	0.1	0.1
Cu	0	0	0	0	0	0
Mn	0	0	0	0	0	0
Fe	0	0	0.1	0	0.1	0.1
Co	0	0	0	0	0	0
Mo	109.2	100.1	92.9	105.9	115.6	88.3
I	528.6	366.9	499.9	515	297.6	329.1
Se	0	0	0	0	0	0
Cr	0	0	0	0	0	0

As a mineral source food, changes in mineral content must be evaluated after gamma irradiation. The results of mineral assays for untreated and irradiated chicken meat are provided in Table 2. The effect of irradiation on the mineral content of chicken is typically different for each macro and micro mineral component. In both types of meat, irradiation treatment tends to increase the content of P and S. After irradiation, the mineral K content of broiler meat tends to increase, whereas it tends to decrease in native meat. In contrary, Ca mineral content in broiler meat tends to decrease following irradiation, whereas it tends to increase in native meat. Regardless of the type of meat, the content of micromineral I tends to decrease after radiation. The effects of irradiation on mineral composition might be explained more precisely, with some studies indicating a decrease in certain minerals and others indicating no substantial changes [25]. We predict that the change in mineral composition after gamma irradiation may be the result of a decrease or elimination in the microbial population. However, more research is necessary. Various studies have demonstrated that gamma irradiation can reduce the populations of aerobic bacteria [9], coliform [26], *Escherichia coli* [3], salmonella [27], yeast, and fungi [28].

4 Conclusion

The gamma irradiation treatment changed the color value of both broiler and native chicken meat. However, no significant differences in pH values were observed. Gamma irradiation may affect the sample's surface image. Following irradiation with 5 and 10 kGy, larger particles and aggregates were observed. This research is essential to determine the differences between native and broiler meat after irradiation treatment, in the prospect of exports.

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